THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

NOVEMBER, 1957

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Telephone:- Victoria 3888

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Trace Elements in Plants

R. L. MITCHELL: 'The Trace-Element Content of Plants.'

Research, 1957, vol. 10, Sept., pp. 357–62.

Review, dealing with some of the conditions governing the occurrence of trace elements in plants, and the effects of such trace elements on the animals eating the plants. References are given to original literature. The paper includes information on investigations currently in progress at the Macaulay Institute for Soil Research, Aberdeen, and suggestions are made with regard to lines of future development in such research. Nickel is among the many trace elements to which reference is made.

Advances in Catalysis

See abstract on p. 198.

NICKEL

North Rankin Nickel Mines, Canada

NORTH RANKIN NICKEL MINES STAFF: 'North Rankin Nickel Mines.'

Canad. Mining Jnl., 1957, vol. 78, Aug., pp. 93–7.

North Rankin Nickel Mines, comprising an area of some 1,540 acres, is situated on Rankin Inlet, an arm of Hudson Bay, North-West Territories, Canada. This paper gives a brief note on its history, from the discovery (in 1928) of the surface outcropping of the ore zone, through to initiation of active mining operations in 1955.

Information is given on the geology of the region, the minerals occurring in the nickel-bearing area, surface and underground equipment and the mining methods used, milling technique, the flotation circuit and other ancillary equipment.

The general method of treating the ore was established by laboratory tests, which showed that, by means of a selective-flotation process, an acceptable copper-nickel concentrate could be made with a ratio of concentration of 3·4 : 1. (Details of flotation technique are given.) The primary flotation concentrate is re-ground and cleaned twice, and a typical composition of the resulting copper-nickel concentrate is given as nickel 13·50, copper 2·58, iron 38·0, sulphur 28·0, insoluble matter 14·31, per cent. The cleaned copper-nickel concentrate is thickened and de-watered through a disc-type filter, and fed to rotating driers, where the moisture content is reduced from 10 to 3 per cent., prior to bagging for shipment to the refinery.

Extraction of Nickel from Cuban Ores

W. E. ANABLE and L. H. BANNING: 'Electric Smelting of Cuban Serpentine and Lateritic Nickel Ores.'

U.S. Bur. Mines, Report of Investigations 5346, July 1957; 24 pp.

The investigation reported was carried out to determine whether serpentine nickeliferous ores would be amenable to direct carbothermic reduction in an electric furnace, to produce a low-carbon ferro-nickel. Continuous-smelting tests showed that over 91 per cent. of the nickel can be recovered in a low-carbon ferro-nickel product containing 25 per cent. or more of nickel. The smelting tests indicated that nickel and cobalt cannot be separated effectively by selective-reduction techniques. Several methods were therefore investigated for separation of the ore into a high-cobalt lateritic fraction and a low-cobalt serpentinitic fraction. Dry screening proved to be the simplest procedure and the most feasible method.

Lattice Spacings of Nickel Solid Solutions

See abstract on p. 199.

Determination of Sulphur in Nickel

G. L. KUKE: 'Determination of Sulphur in Nickel by the Evolution Method.'

Analytical Chemistry, 1957, vol. 29, Aug., pp. 1227–8.

A rapid method for determination of sulphur in nickel is urgently needed in certain stages of vacuum-tube development. In considering possible techniques, the conclusion was reached that an evolution method might be applicable, provided that means could be found for speeding-up the solution of nickel in hydrochloric acid, and that it could be demonstrated that all the sulphur in nickel is present as sulphide.

This paper reports a method worked out in the Bell Telephone Laboratories. Dissolution of nickel in hydrochloric acid is greatly accelerated by the addition of a small amount of platinic chloride. During solution platinum is deposited, as platinum black, on the nickel, thus forming electrolytic couples

in which the platinum is cathodic. Because of the low overvoltage of hydrogen on platinum black, dissolution of the nickel is very rapid, e.g., a 1-gram sample of reasonably well sub-divided nickel, which would normally require about one hour for dissolution, can be dissolved in less than 15 minutes.

In order to demonstrate that all the sulphur in nickel is present as sulphide, various types of nickel were analyzed, by the proposed evolution method and by an independent method which measured total sulphur content regardless of state of oxidation. The results of the determinations made by the two methods showed close agreement, indicating that the sulphur in all types of nickel is present solely as acid-soluble sulphide and that the proposed method can be satisfactorily used.

Full details of procedure are given, with drawing of the distillation apparatus used.

Determination of Magnesium in Cathode Nickel

H. POHL: 'A Photometric Method for the Determination of Magnesium in Cathode Nickel, using Eriochrome Black T.'

Zeitsch. f. analytische Chemie, 1957, vol. 155, Mar. 1, pp. 263–7.

Successful results with Eriochrome Black T, in determining magnesium in zinc and aluminium, and in S.G. iron, led to investigation of the suitability of that reagent for estimation of magnesium in cathode nickel, in which the quantities present are of the order of 0·005–0·2 per cent. In a buffered solution of pH 10·6 the magnesium present forms, with Eriochrome Black T, a water-soluble red complex, which is photometrically estimated. (Nickel and other elements are first removed by precipitation with oxine and subsequent oxine-carbaminate chloroform extraction.)

Nickel Catalysts

'Proceedings of the International Congress on Catalysis, Philadelphia, Pa., 1956.'
Edited by A. FARKAS.

Published by *Academic Press, Inc., New York, N.Y.*, as Volume 9 of 'Advances in Catalysis and Related Subjects'; 847 pp.

The purpose of the Congress was to assemble scientists engaged in study of catalysis and related fields, and representative of as many countries and schools of thought as possible. More than 700 individuals, from 20 different countries, were present.

The papers were grouped in four major symposia:—

'*Chemistry and Physics of Solid Catalysts*', covering hydrogenation and hydrogen-exchange reactions, physical properties of catalysts, electronic properties, and catalytic acivity.

'*Homogeneous Catalysis and Related Effects.*'

'*Surface Chemistry and its Relation to Catalysis.*'

'*Techniques and Technology of Catalysis.*'

This Session was concerned with the catalytic reactions of hydrocarbons, with tracer and other techniques, and with miscellaneous catalytic reactions.

The volume contains all but two of the papers presented, together with the major part of the discussion.

In addition to the basic interest of the subject in relation to nickel, the following papers report specific investigations on nickel-containing materials.

R. L. BURWELL: 'Stereochemistry and Heterogeneous Catalysis', pp. 13–14.

Abstract of review paper presenting aspects of stereochemistry of heterogeneous catalysis which may aid in an understanding of the mechanisms of hetero-catalytic reactions. Includes data on the isotopic exchange reaction between deuterium and (+)3-methyl-hexane on nickel catalysts. The full paper will be published later.

R. E. CUNNINGHAM and A. T. GWATHMEY: 'The Reaction of Hydrogen and Ethylene on Several Faces of a Single Crystal of Nickel', pp. 25–36.

The reaction of hydrogen and ethylene was studied on the (100), (111), (110) and (321) faces of nickel single crystals, at temperatures from 50° to 200°C.

D. O. SCHISSLER, S. O. THOMPSON and J. TURKEVICH: 'A Study of the Ethylene-Deuterium Catalytic System', pp. 37–43.

A report is given of the reaction of ethylene and deuterium over nickel on kieselguhr, nickel wire, palladium on charcoal, and palladium on silica gel catalysts, at temperatures from −98° to 110°C. and at pressures of 50 atm. to fractions of an atmosphere. The reaction of deuteroethylene and hydrogen was also studied.

D. A. DOWDEN, N. MACKENZIE and B. M. W. TRAPNELL: 'Hydrogen-Deuterium Exchange on the Oxides of Transition Metals', pp. 65–9.

Nickel-oxide catalysts were used in some of the experiments reported.

P. W. SELWOOD: 'Magnetic Determination of Structure and Electron Density in Functioning Catalytic Solids', pp. 93–106.

The paper includes reference to a magnetic method which may be used to reveal the distribution of particle sizes in supported nickel catalysts.

H. E. FARNSWORTH and R. F. WOODCOCK: 'Effects of Radiation Quenching, Ion-Bombardment, and Annealing on Catalytic Activity of Pure Nickel and Platinum Surfaces. II. Hydrogenation of Ethylene (continued). Hydrogen - Deuterium Exchange', pp. 123–30.

This report is supplementary to one which is to be published shortly in '*Industrial and Engineering Chemistry.*'

R. SUHRMANN and G. WEDLER: 'A New Method for the Study of Elementary Processes in Catalytic Decomposition Reactions', pp. 223–8.

By the decomposition of formic acid on a nickel

catalyst, it is shown how the elementary processes of a decomposition reaction can be found if the direction of the electron transfer in the adsorption of possible decomposition product is known. The kind of electronic interaction is investigated by measuring the change of resistance of a transparent nickel layer during chemisorption.

H. C. ROWLINSON and R. J. CVETANOVIĆ: 'The Dehydrogenation of Butenes on Semiconducting Oxide Catalysts', pp. 243–51.

The conductivity of the oxides of zinc, iron, and nickel is known to be highly sensitive to small amounts (<1 mole %) of oxides of similar cation radius, but different valency (e.g., $Li+$, $Al^{3}+$, $Ga^{3}+$, $Cr^{3}+$ and $Ti^{4}+$). The activity and selectivity of such promoted catalyst pellets have been measured for the dehydrogenation of butene-1 to butadiene at temperatures between 500° and 650°C., in the presence of 10–20 vol. of steam as a diluent gas. The decomposition of butadiene was studied as a separate reaction.

H. H. UHLIG: 'The Rôle of Catalysis in Corrosion Processes', pp. 379–92.

Includes supporting data on corrosion tests on austenitic chromium-nickel stainless steels.

R. E. SCHLIER and H. E. FARNSWORTH: 'Low-Energy Electron Diffraction Studies of Oxygen Adsorption and Oxide Formation on a (100) Crystal Face of Nickel Cleaned Under High-Vacuum Conditions', pp. 434–40.

S. J. TEICHNER, R. P. MARCELLINI and P. RUÉ: 'Adsorption of Gases by Pulverulent Oxides. I. Nickel Oxide', pp. 458–71.

R. P. EISCHENS and W. A. PLISKIN: 'Infrared Study of the Catalyzed Oxidation of CO', pp. 662–8.

Infrared technique, which make it possible to obtain spectra of adsorbed molecules while reactions are in progress, was used to study the oxidation of CO over a nickel/nickel-oxide catalyst system.

Trace Elements in Plants

See abstract on p. 197.

ELECTRODEPOSITION AND OTHER COATING METHODS

Properties of Nickel Electrodeposits

T. E. SUCH: 'The Physical Properties of Electrodeposited Metals.' *Metallurgia*, 1957, vol. 56, Aug. and Sept., pp. 61–6, 121–4.

The article is essentially a review of some of the literature, supported by the author's own observations. It covers the significance, in engineering and other applications, of 'the most critical physical properties of plated metal', viz., tensile strength, ductility, hardness and internal stress. The *bibliography* contains 30 selected references which are correlated with the text: most of the items relate to nickel and/or chromium deposits.

After defining the properties which are to be considered, and noting the wide range of variations which can be obtained in any one property by appropriate adjustment of the conditions of deposition, the author discusses the various applications of electrodeposited metals, with reference to the deposition techniques by which the properties most suitable for the respective uses can be secured. *Inter alia*, consideration is given to applications calling for wear-resistance, fatigue-resistance, and specially low internal stress. The influence of the physical properties of a deposit on its corrosion-resistance are briefly dealt with, as are criteria by which it is possible to evaluate the buffability of a coating. In reviewing factors which influence the physical properties of electrodeposited metals, consideration is given to the effects of substances co-deposited with the metals; the effects of various organic substances are discussed and attention is directed to the deleterious influence of hydrogen.

The significance of solution-composition and operating conditions, as controlling the physical properties of deposits, is exemplified by reference to their effects on electrodeposited chromium, copper, zinc and nickel. In the section relating to nickel, the properties of dull, semi-bright and bright deposits, obtained from baths of various types, are considered, with notes on the effects of organic and of metallic impurities.

The final section of the review is concerned with the various procedures used to determine the properties of electrodeposited coatings: tensile strength, ductility, hardness, and internal stress. Methods which have been devised to overcome the difficulties inherent in testing material so thin as electrodeposited coatings are described.

NON-FERROUS ALLOYS

Lattice Spacings of Nickel Solid Solutions

W. B. PEARSON and L. T. THOMPSON: 'The Lattice Spacings of Nickel Solid Solutions.'
Canadian Jnl. Physics, 1957, vol. 35, Apr., pp. 349–57.

Measurements of the lattice spacings of nickel solid solutions containing as solutes the transition-metal elements of the First Long Period provide one of the most systematic sources of information on lattice-spacing variation in transition-metal alloys. The authors refer to one aspect of these which is of particular interest, namely the definite kinks reported in the lattice-spacing/composition curves of vanadium, chromium, manganese and iron dissolved in nickel. Brief review is made of relevant work, with discussion of the various explanations which have been suggested to account for the kinks.

This paper reports new measurements on the lattice spacings of chromium, manganese, cobalt, zinc, germanium, indium and tin solutes in nickel, and discusses the relationship of lattice distortion and the depression of the solidus temperature.

Nickel-Aluminium Bronze Marine Propellers

'Nickel-Aluminium Bronze Propellers. Russian Liner to Fit British Propellers.'
Times, 1957, Aug. 24, p. 6.

The 7,500-ton Russian liner 'Baltika', which plies between London and Leningrad, recently entered a London dry dock to be fitted with twin propellers of Novoston bronze, a nickel-aluminium-copper alloy which has specially good corrosion- and wear-resisting properties. The material was developed by Messrs. J. Stone and Co. (Charlton), Ltd. Each propeller for the 'Baltika' weighs 5½ tons.

Some 400 propellers made in Novoston have already been made or ordered, but those for the 'Baltika' are the first to be installed in a ship from an Iron Curtain country.

Welding of Monel Protection Tubes for Offshore Installations

'Welding Treasure Islands.'
Welding Jnl., 1957, vol. 36, Aug., p. 813.

This illustrated note deals with welding methods used in assembly of sections of Monel wrapping used for the protection of offshore oil-drilling platforms in the Gulf of Mexico and elsewhere. Rapid corrosion of the steel legs of the platforms is being prevented by covering with sheet of 20-gauge Monel. Longitudinal butt welds and circumferential fillet welds of these wrappings are made by manual tungsten-arc argon-shielded welding, and much saving in man-hours has been made possible by the use of mechanized submerged-arc welding for attaching the doubler plates to the legs of the main structure.

NICKEL-IRON ALLOYS

Nickel-Iron Alloys Having Special Physical Properties

C. GORDON SMITH: 'Nickel Alloys with Special Physical Properties.'
Metal Industry, 1957, vol. 91, Aug. 23 and 30, pp. 145–7, 169–70.

In addition to the wide variety of nickel-containing alloys which are well known in the chemical engineering, high-temperature engineering and other fields, there is a range of 'special' alloys the applications of which depend mainly on properties directly or indirectly related to their ferromagnetic characteristics. The technical importance of these alloys is of a very high order and their successful development and utilization has been of major significance in the spectacular advances which have been made during recent years in the telecommunication and the instrument industries.

This article, based on a recent lecture, contains a condensed review of the properties and applications of representative types of nickel-iron-base 'special' alloys. Consideration is given to the characteristics of the nickel-iron system, as a background to understanding of the properties inherent in the various alloy groups in that series. Properties and resultant applications are then discussed in sections relating, respectively, to

Low-Expansion Alloys (e.g., Invar and the Nilo series), used in temperature-control devices glass-to-metal seals, etc.

Constant-Modulus Alloys (e.g., Elinvar, Ni-Span and Nivarox), used in watch hair-springs, springs of precision weighing machines, aneroid capsules, Bourdon tubes, and for frequency control in electronic equipment.

High-Permeability Alloys (e.g., Permalloy C and Mumetal), used in communication engineering, e.g., for cores of transformers carrying alternating current over a wide range of frequencies, and in transformers used in instrumentation in power-distribution systems.

Permanent Magnets (e.g., Alnico and Alcomax), used in loudspeakers, telephone receivers, electricity meters and other applications in the communications industries, and in magnetic chucks and holding devices employed in heavy engineering.

Alloys having Magnetostrictive Properties, used in generation of ultrasonic waves, the magnetostriction property being utilized for conversion of electrical to mechanical energy, and *vice versa*. The most important application of the magnetostrictive materials is in echo-sounding devices and related equipment. Nickel is the most widely used material, but nickel-iron alloys are also suitable in certain applications.

Magnetic Compensation Alloys. Here nickel-iron alloys containing about 30 per cent. of nickel find useful application. Such alloys show rapid change in magnetic properties with change in ambient temperature, and on this account they find use in the compensation of certain instruments, notably speedometers of the drag-disc type and kilowatt-hour electricity meters. The compensating alloy is used as a shunt to the permanent magnet which controls the indicating system, and the resulting flux diversion can be made to compensate temperature errors inherent in the electrical system.

CONSTRUCTIONAL STEELS

Variations in Transformation Characteristics within Nickel-Alloy Steel Samples

W. STEVEN and D. R. THORNEYCROFT: 'Variations in Transformation Characteristics within Samples of an Alloy Steel.'
Jnl. Iron and Steel Inst., 1957, vol. 187, Sept., pp. 15–32.

Several investigations have established the existence

of longitudinal and transverse variations of hardenability within steel bars and billets of normal commercial quality. It has been shown that, in general, the material near the axis of a rolled bar has lower hardenability than that near the surface and that there is frequently a zone of peak hardenability at an intermediate position. It has also been demonstrated that the hardenability of the material near the axis, and the position and magnitude of the line of peak hardenability, vary along the length of the bar, although the hardenability of the material near the surface has proved to be fairly uniform. Although some variations in hardenability are undoubtedly due to macrosegregation of carbon and alloying elements, the majority of such variations cannot be explained on that basis, and the object of the work described in the present paper was to assess the extent to which longitudinal and transverse variations of hardenability occur within the wrought product of normal commercial ingots of medium-alloy steel, and to explain, if possible, the origin of the variations.

Variations of hardenability within a sample of steel will necessarily give rise to differences in isothermal-transformation characteristics, and, in this research, the study of such variations was used as a method of investigation. Survey of the isothermal-transformation characteristics within unforged ingot samples of a low-alloy 0·37-0·38 per cent. carbon nickel-chromium-molybdenum steel, and within bars and wire produced from them, leads to the conclusion that the variations are due largely to differences in the intensity of microsegregation of alloying elements within the different samples.

Formation of Martensite in Nickel Steel

R. PRIESTNER and S. G. GLOVER: 'A Re-Examination of the Growth of Martensite in a 1·5 per cent. Carbon, 5 per cent. Nickel Steel.' *Acta Metallurgica*, 1957, vol. 5, Sept., pp. 536-8.

Work reported by Ko (*ibid.*, 1954, vol. 2, p. 75) demonstrated that tempering of a quenched 1·5 per cent. carbon, 5 per cent. nickel steel led to the appearance, on subsequent microscopic examination at room temperature, of light-etching rims round the previously-formed dark-etching martensite plates. The observation was construed as showing that a coherent growth of martensite occurred during tempering.

Experimental ageing treatments carried out by the present authors, on specimens of the same material, do not support Ko's explanation. Attention is, however, directed to the significance of the authors' observation that martensitic rims are formed after ageing at moderate temperatures, in that this phenomenon constitutes an enhancement of the normal athermal formation of martensite, since transformation re-commences at a temperature above that to which the steel was initially quenched. This effect is in remarkable contrast to the usual effect of ageing a steel after partial transformation to martensite, which is to stabilize the remaining austenite with respect to further martensitic transformation.

A.I.S.I. Standard Steels

'A.I.S.I. Standard Alloy-Steel Compositions.' *Metal Progress*, 1957, vol. 72, Aug., p. 96B.

Compositions of open-hearth and electric-furnace alloy steels standardized by the American Iron and Steel Institute, as of March 1957. The list includes various types of nickel-chromium, nickel-chromium-molybdenum and nickel-molybdenum steel.

British Standards for Steel Castings

See abstract on p. 207.

High-Tensile Nickel-Alloy Constructional Steel

'New High-Yield Strength Plate Steel Developed.' *Nickel Topics*, 1957, vol. 10, No. 7, p. 8.

This article gives a brief history of the development (under the auspices of the U.S. Navy) of a weldable grade of high-strength low-alloy nickel-containing steel (HY-80) and a proprietary grade of slightly higher strength (T-1). HY-80 is covered by U.S. Military Specification MIL-S-16216B Navy, for which the chemical requirements are as follows:—

	Plate Thickness lb./sq. ft.	
	To 51·0 (1¼ in.) incl. %	Over 51·0 %
Carbon, max. ..	0·22	0·23
Silicon	0·10-0·40	0·10-0·40
Manganese ..	0·12-0·38	0·12-0·38
Sulphur, max. ..	0·040	0·040
Phosphorus, max. ..	0·045	0·045
Nickel	1·93-2·57	2·68-3·32
Chromium	0·84-1·46	1·29-1·91
Molybdenum ..	0·13-0·27	0·37-0·63

The steel, in the quench-and-tempered condition, is required to show the following properties:—

	p.s.i.	t.s.i.
Yield Strength (0·2 per cent. offset)	80,000-95,000	35·5-42·5
Elongation, in 2 in., per cent.	20·0	
Charpy Impact, V notch at −120°F. (−84°C.), ft.-lb.	50*	
*For plate 20·4 to 61 lb./sq. ft. (¼ to 1½ in. thick)		

The steel has been successfully used in high-strength members of ships' structure and for hulls of submarines, and consideration is being given to its application in reactor vessels for nuclear power plants, which would require plate of up to 6 in. thickness.

For manual arc welding of this steel, nickel-molybdenum-vanadium steel electrodes Class 206 or 230 (MIL-E-986B) are suitable if the steel is to be used in the as-welded condition. If stress-relief treatment is to be applied after welding, Class E 10015 or E 10016 (MIL-E-18038) electrodes should be employed. A wire developed for inert-gas-shielded metal-arc welding of high-strength steels such as HY-80 and T-1 has the nominal composition: carbon 0·06, silicon 0·40, manganese 1·20, sulphur 0·025 max., phosphorus 0·025 max., nickel 1·20, molybdenum 0·40, vanadium 0·13, per cent. Typical mechanical properties of the weld metal, in the as-welded condition, are given as:

	p.s.i.	t.s.i.
Tensile Strength ..	119,000	53
Yield Strength ..	109,000	48·5
Elongation, % in 2 in.	20·0	
Reduction of Area, %	58·0	
Brinell Hardness ..	262	

V-notch Charpy impact properties of the weld metal measured in one series of tests were:—

°F.	°C.	ft.-lb.
70	21	78·82
0	−18	44-58
−50	−45·5	26-34
−100	−73	12-15

Columbium (Niobium), Boron, Calcium and Zirconium in Nickel-containing Materials

See abstract on p. 207.

Steels Used in Mining Machinery

'Special Steels used in Machinery for the Iron Mines.' *Aciers Fins et Spéciaux*, 1957, No. 26, July, pp. 36–42.

The mechanization of the French iron mines has called for introduction of special steels for a number of components. This article reviews the use of such steels in five classes of equipment: drilling machines, scraper loaders, continuous loaders, shuttle wagons and underground locomotives. The compositions and properties of steels which have been selected for components falling within these classes are given, with details of the AFNOR* specifications to which they conform. Among the parts for which nickel-alloy steels of various grades are specified are the following: gears and pinions, chain wheels, shafts, rake conveyor chains, rakes, valve slides of hydraulic equipment, screws and bolts.

* AFNOR: Association Française pour Normalisation

HEAT- AND CORROSION-RESISTING MATERIALS

Nimonic Alloys: Design Data

HENRY WIGGIN AND CO., LTD.: 'The Nimonic Alloys: Design Data.'

Publn. 1303, Sept. 1957; 64 pp.

This publication, which is the fifth edition of the handbook on Nimonic alloys, has been extensively revised and amplified. It provides comprehensive information on Nimonic DS, 75, 80, 80A, 90, 95 and 100, including tabular data on composition, heat-treatment, physical properties, creep and fatigue characteristics and torsional properties, together with graphical summaries illustrating fatigue and creep behaviour under various conditions.

New data incorporated in this edition include information on the creep and fatigue properties of Nimonic 100, additional long-time creep values for Nimonic 80 and 90 at various temperatures, recommendations on various heat-treatments which may be used to vary the combination of high-temperature properties obtainable, and oxidation behaviour of five of the alloys at temperatures in the range 800°–1100°C.

Certain of the Nimonic alloys are supplied also in cast form, under the designation 'Nimocast'. Information on the cast forms is given in *Wiggin Publication No.* 1311: see below.

Nickel-Chromium-base Casting Alloys: Nimocast Series

HENRY WIGGIN AND CO., LTD.: 'Nimocast Alloys. Some Properties of Nickel-base Casting Alloys for High-Temperature Service.'

Publn. 1311*, 1957, 24 pp.

Based on paper by D. R. WOOD and J. F. GREGG, published in *Metal Treatment*, 1957; vol. 24, Aug., pp. 317–24.

The paper presents and discusses data on the tensile, impact, hardness, stress-rupture and casting properties of six alloys of nickel-chromium base. These materials of the Nimocast series have for some time been in supply under other names: for key see below:—

Nimocast 75 (Nimonic C75)	Nimocast 242 (C242)
Nimocast 80 (Nimonic CC)	Nimocast 257 (MC57)
Nimocast 90 (Nimonic CB)	Nimocast 258 (MC58)

* *We shall be pleased to supply a free copy of this publication.*

Nimocast 75, 80 and 90 correspond to the wrought alloys of similar numbers; Nimocast 242, 257 and 258 are relatively new alloys. Nominal compositions of the six materials are shown in the Table on p.204, together with a broad outline of the properties of the respective types and the recommended temperatures for pouring and for heat-treatment.

Nimocast 257 was developed in connexion with the centrifugal casting of engine rings for gas turbines, to meet the need for an alloy which, at 650°C., would provide a 0·1 per cent. tensile proof stress of 15 tons per sq. in., with an elongation, on fracture, of 10 per cent.

In Nimocast 258, which is similar in composition to Nimonic 100, the most creep-resistant wrought alloy of the Nimonic series, the composition has been modified by increase in titanium and adjustment of the titanium: aluminium ratio, to produce a casting alloy having useful creep- and rupture-resistance at temperatures above 950°C.

Nimocast 242 was developed by Rolls-Royce, Ltd., for investment-cast applications in which the requirement was for high resistance to thermal shock and good creep properties at temperatures of the order of 1000° to 1050°C. There is evidence that in this alloy room-temperature and stress-rupture properties, particularly in the lower part of the range covered, are dependent on casting conditions, especially on pouring temperature.

The paper ends with notes on the casting properties and foundry procedures suitable for the alloys, and on control of composition.

The authors summarize the potential applications of the alloys as follows: 'The fields of application which can be envisaged for Nimocast 75 and Nimocast 80 are relatively limited, but Nimocast 90 which, by comparison, shows superior castability and stress-rupture properties, could be adopted for service involving moderate stresses and temperatures up to, say 870°C. When still better stress-rupture properties at the highest temperatures are required Nimocast 258 may be chosen, and this alloy has good casting characteristics. The alloys Nimocast 242 and Nimocast 257 may be selected for applications in which there is a need for their specific characteristics, i.e., in the one case exceptionally high resistance to thermal shock, and in the other high tensile ductility at 650°C.'

Incoloy 901: Data Sheet

INTERNATIONAL NICKEL CO., INC.: 'Incoloy 901: Nickel-Iron-Chromium Alloy.'
Published by *International Nickel Co., Inc.*, July 1957; 4 pp.

Incoloy 901 is a new heat-resisting material of the following composition: nickel 40·00, chromium 13·00, titanium 2·41, molybdenum 6·00, per cent., iron balance. The material has been developed for gas-turbine components in which high tensile, creep, and rupture strength is needed in the range 1000°–1400°F. (540°–760°C.). The alloy can be forged and welded, and it has the advantage of a coefficient of thermal expansion so closely similar to that of alloy steel that the two types of material can be joined without special precautions necessitated by differential expansion. Together with values for coefficients of thermal expansion over various ranges, this publication contains information on density, modulus of elasticity, tensile strength, and 1,000-hour rupture life.

Inconel 702: Data Sheet

INTERNATIONAL NICKEL CO. INC.: 'Inconel 702: Aluminium-containing Nickel-Chromium Alloy.'
Published by *International Nickel Co., Inc.*, 1957; 4 pp.

Inconel 702 is a high-aluminium, low-titanium modification of standard Inconel, developed to give enhanced oxidation-resistance at extremely high temperatures. The composition is given as follows: carbon 0·10 max., manganese 1·0 max., silicon 0·7 max., sulphur 0·01 max., iron 2·0 max., copper 0·5 max., chromium 14·0–17·0, aluminium 2·75–3·75, titanium 0·25–1·0, per cent., nickel balance. The high aluminium content improves the protective action of the oxide at all temperatures up to incipient melting. The properties of the alloy, which in the annealed condition is readily formed and machined, can be enhanced by an age-hardening treatment.

The publication gives data on physical constants (density, coefficient of thermal expansion over various temperature ranges, and modulus of elasticity), tensile properties, stress-rupture, and oxidation-resistance. In the annealed condition, Inconel 702 has good weldability.

Powder-Reinforced High-Temperature Alloys

J. D. BURNEY: 'A Study of the Possibility of Reinforcing High-Temperature Alloys by Addition of Refractory Powders.'
Wright Air Development Center Report 56-190, May 1956; 36 pp.

The project of which this work forms a part is planned to develop high-temperature materials which will show adequate strength and ductility at both room temperature and the service temperatures involved in operation of gas-turbine blading, coupled with good resistance to oxidation, and to deterioration under thermal shock. The alloy composition chosen for the tests reported was the 80–20 nickel-chromium type, which was reinforced by addition of the following types of stable refractory oxide: Al_2O_3, TiO_2, ZrO_2, Cr_2O_3 and SiO_2. A study was made of the influence of type of reinforcing oxide, amount used, particle size of the oxide, and dispersion of the oxide in the alloy. In most of the experiments the amount of oxide was within the limits 0·1–2·0 per cent. The effects of fabrication procedure were studied by examination of specimens prepared by five different techniques regularly used in powder-metallurgy production of solids, and some attention was also given to other fabricating procedures such as vacuum sintering and internal-oxidation. The

Nominal Compositions of Nimocast Alloys

(*see abstract on p. 202*)

Alloy	Nominal Composition										Special Properties	Recommended Heat-Treatment†	Liquidus °C.	Recommended Pouring Temp. °C.
	C %	Si %	Mn %	Cr %	Co %	Fe %	Ti %	Al %	Mo %	Ni %				
Nimocast 75 ..	0·1	0·4	0·3	20	—	5 max.	0·4	0·2	—	Bal.	High resistance to oxidation	As-cast, or 4-8 hours 1080°C., A.C.	1410	1510*
Nimocast 80 ..	0·05	0·4	0·3	20	—	5 max.	2·4	1·2	—	Bal.	Useful creep-resistance at temperatures up to approx. 750°C., and high mechanical properties at room temperature	As-cast, or 4-8 hours 1080°C., A.C.,+ 16 hours 700°C., A.C.	1380	1480*
Nimocast 90 ..	0·1	0·4	0·3	20	16	5 max.	2·4	1·2	—	Bal.	As Nimocast 80, but useful creep-resistance at temperatures up to approx. 870°C., with improved castability	As-cast, or 4-8 hours 1080°C., A.C.,+ 16 hours 700° C.,A.C.	1380	1480*
Nimocast 242 ..	0·3	0·3	0·3	20	10	1 max.	0·3 max.	0·2 max.	10	Bal.	High resistance to thermal shock	As-cast	1370	1410*
		Si + Mn 1% max.												
Nimocast 257 ..	0·8	0·04	0·3	20	16	2 max.	1·6	0·9	—	Bal.	Good combination of 0·1% proof stress and ductility in tensile tests at 650°C.	4-8 hours 1080°C., A.C., + 16 hours 700°C., A.C.	1390	1490**
Nimocast 258 ..	0·2	0·4	0·3	10	20	2 max.	3·7	4·8	5	Bal.	Very good creep-resistance at temperatures up to 1000°C., and good castability	As-cast, or 4-8 hours 1000°C., A.C.,+ 16 hours 850°C., A.C.	1310	1430*

* For investment-casting. ** For centrifugal-casting. † A.C., Air-Cooled.

main conclusions drawn from the experiments are summarized below:

Of the specimens made by the 'press-sinter' method of fabrication, bars containing 1·0 per cent. TiO_2 showed better stress-rupture properties than bars containing any other of the oxide additions studied. Hot-forging techniques were found to be applicable for working bars containing 1·0 per cent. or less of the oxide additions.

An 80-20 nickel-chromium alloy reinforced with 1 per cent. of Al_2O_3 and densified by a liquid-phase sintering technique gave stress-rupture properties superior to those of an 80-20 nickel-chromium alloy. The room-temperature impact and tensile strength of the material appeared adequate, its resistance to oxidation was satisfactory, and its thermal-shock properties were good.

Elevated-Temperature Properties of Metals

INSTN. METALLURGISTS: 'Behaviour of Metals at Elevated Temperatures.'

Published, for the Institution, by *Iliffe and Sons, Ltd., London; Philosophical Library, New York*, 1957; 122 pp.

Price: Members 15/6. Non-Members 21/-.

The book contains the texts of lectures given at the Tenth Refresher Course of the Institution of Metallurgists, held in Oct. 1956. The papers, the scope of which is shown in the following abstracts, cover the effects of temperatures ranging from only slightly above normal to the maximum operational temperatures of the respective materials considered.

N. P. ALLEN: 'The Engineering Properties of Materials at High Temperatures', pp. 3-30.

The engineering properties of metals are defined as 'those which must be taken into account by an engineer in designing a component to withstand the mechanical and thermal stresses to which it will be exposed and to the chemical attack of its surroundings'. In this paper discussion is confined to the following characteristics, as influenced by temperature: stability of physical properties, elastic constants and coefficient of expansion, resistance to plastic deformation, creep and fatigue behaviour, behaviour under fluctuating temperatures, corrosion-resistance. (Other properties, such as castability and machinability, are included only in so far as they affect the mechanical behaviour of the component as part of a structure.)

This review is followed by a brief account of principles which should be followed in developing alloys required to have good high-temperature mechanical properties.

The paper comprises a relatively general treatment of the subject, designed to form an introduction to the more detailed discussion of individual materials by other contributors.

G. MEIKLE: 'The Effect on Metals of Temperatures up to 450°C', pp. 33-63.

The author deals with the subject from the standpoint of the aeronautical engineer. His review of the effect of elevated temperatures on metals is therefore confined to aspects which are of interest in aircraft design, i.e., the effect of temperature on materials used in airframe structures.

Introductory reference is made to the various ways in which such structures are either intentionally heated, or may become heated during operation: this section includes brief discussion of problems arising from kinetic heating which occurs under very fast flying conditions.

The introduction is followed by a detailed review of the high-temperature behaviour of individual materials (aluminium alloys, sintered aluminium powder (S.A.P.), magnesium alloys, aluminium-nickel-iron bronze, titanium and its alloys, and steels which are used in airframe structures). Particular attention is devoted to the aluminium alloys, in view of their extensive use in aircraft construction.

The paper ends with a discussion of factors which should be considered in selecting airframe structures which may operate at elevated temperatures.

L. B. PFEIL: 'Non-Ferrous High-Temperature Materials', pp. 67-90.

By general agreement, non-ferrous alloys are defined in this symposium as those containing not more than 50 per cent. of iron. The author of this paper emphasizes, however, that this definition is an arbitrary one, since there is no fundamental boundary between the nickel-chromium austenitic steels and the most important series of alloys in the high-temperature field, the iron-nickel-chromium system, the properties of which vary over a wide range in relation to their iron contents.

Supplementing the preceding contribution, the low-temperature limit of the materials considered in this paper was set at 500°C.

The opening section contains a review of the types of alloy which have proved satisfactory for high-temperature applications, and of those which are currently being examined for that purpose. This involves discussion of the properties of established alloys based on nickel and on cobalt (exemplified, respectively, by Nimonic 80A and G.32). The high-temperature applications of the platinum-group metals are also briefly mentioned. Similarly, since current research on the development of improved alloys for high-temperature service is centred to a considerable degree on the use of base metals which have higher melting points than those in present use, e.g., molybdenum, chromium and titanium, recent work on alloys containing high percentages of these three elements is also briefly reviewed. In this connexion, mention is made of attempts to overcome the susceptibility of molybdenum to oxidation, by formation, on the alloy surface, of layers of nickel molybdate, or by spraying and interdiffusion of coatings containing chromium, aluminium and silicon.

Properties essential in any alloy intended for service at high temperatures are then considered: resistance to corrosive attack, strength at service temperatures,

fatigue strength, and ease of manipulation. The discussion is illustrated by reference to relevant data on established high-temperature alloys, confined mainly to the nickel-base alloys of the Nimonic series, the compositions of which are tabulated. In addition, consideration is given to problems involved in testing and assessing the active merits of different alloys, on the basis of creep, rupture and fatigue properties. Oxidation-resistance is also discussed.

The author indicates how, by careful control of composition and suitable modification of such factors as solution- and precipitation-heat-treatment and hot- and cold-working, it is possible to develop alloys having the optimum combination of high-temperature properties. Data on Nimonic 90 are used to illustrate the effect of such modifications

The paper ends with a brief evaluation of the high-temperature properties of some cast nickel- and cobalt-base alloys, a general review of progress in high-temperature materials during the past twenty years, and a discussion of possible future trends.

W. E. BARDGETT : 'High - Temperature Steels', pp. 93–122.

The author's aim is 'to present the broad picture, relating to the more established steels, rather than to list a wide variety of compositions and properties'. Steels are classified according to their type (carbon, low-alloy, intermediate-alloy, 12 per cent. chromium, and austenitic steels). After a brief résumé of the relationship between scaling and basis composition, and the beneficial effect of additions of chromium (and, within certain limits, of silicon), the various groups of steel are reviewed under two headings: high-temperature strength and high-temperature ductility.

The carbon steels are discussed with respect to the improvements in their creep properties which have been made since they were first considered for high-temperature applications: particular reference is made to the influence of silicon and aluminium. The low-alloy steels are discussed in two sections, dealing, respectively, with typical ferritic-pearlitic and martensitic compositions. Consideration of the martensitic steels is confined to the chromium-molybdenum-vanadium-tungsten steels and the relationship between the vanadium:carbon ratio and creep-resistance; the section on intermediate-alloy ferritic steels deals with the development of a chromium-molybdenum-titanium steel for use at temperatures of the order of 620°C. A brief note is added on a 12 per cent. chromium steel suitable for applications above that temperature.

At temperatures higher than 600°C., in cases where a combination of scale-resistance and creep-resisting properties is required, the chromium-nickel austenitic steels are used: reference is made to typical compositions and applications. It is pointed out that such steels depend mainly upon precipitation reactions for their high-temperature strength, and that careful control of the precipitation process is an essential factor in securing optimum properties. The desirability of long-time testing as a basis for design is emphasized by reference to unexpected effects observed in laboratory tests on 18–12–1 chromium-nickel-niobium steel, and on 30–20–1·1 nickel-chromium-titanium steel.

Reference is also made to work on a high-carbon austenitic steel containing nickel, chromium and cobalt with additions of three strong carbide-forming elements (tungsten, molybdenum and niobium). Tests have shown that the various carbide-forming elements control creep strength through their influence on the precipitating phases, rather than by their effect on the matrix solid solution.

The paper ends with a brief review of the significance of ductility in high-temperature steels.

Elevated-Temperature Lubrication of Inconel Alloys

M. B. PETERSON and R. L. JOHNSON: 'Friction Studies of Graphite and Mixtures of Graphite with Several Metallic Oxides and Salts at Temperatures to 1000°F.'

Nat. Advisory Committee for Aeronautics, Tech. Note 3657, Feb. 1956; 16 pp.

The use of solids as lubricants offers a method of reducing friction and wear between moving metal surfaces at high temperatures at which liquid lubricants are unsuitable. Dry graphite powder has proved effective, but many of the factors which affect its lubricating characteristics are not yet completely understood. The investigation described in this report was undertaken to secure further information on the action of graphite and of graphite mixed with several metallic salts and oxides. Friction studies were made at temperatures up to 1000°F. (540°C.), at a low sliding velocity (5·7 ft./min.), and with a load of 40 lbs. supported on three $\frac{3}{16}$-in. radius hemispherical contacts. Various materials, including Inconel, Inconel X and tool steel, were lubricated by synthetic graphite and by mixtures of graphite with oxides of lead and cadmium as well as with sulphates of sodium and cadmium. All the materials were used in the form of fine powders.

In tests with Inconel sliders and Inconel X discs, graphite lubricated satisfactorily at 1000°F. (540°C.), but at 650°F. (345°C.) it would not form a lubricating film: high friction and severe galling took place. It was presumed that the superior behaviour at the higher temperature was due to the greater amount of oxide then present, and this was confirmed in tests which showed that on steel, which oxidizes at a lower temperature than Inconel, graphite was an effective lubricant to a lower temperature than with Inconel. It was established that for cast Inconel on Inconel X failure to lubricate occurred between approximately 150° and 800°F. (65° and 425°C.), whereas for steel the temperature below which lubrication failed was 475°F. (245°C.).

Mixtures of metallic compounds and graphite were effective lubricants from room temperature

to 1000°F. (540°C.), provided that no reaction occurred between the metallic compounds and the graphite.

British Standards for Steel Castings

BRIT. STANDARDS INSTN.: 'Steel Castings for General Engineering Purposes.' *B.S.* 3100: 1957. Price 7/6.

Between 1945 and 1953 sixteen separate specifications for steel castings for general engineering purposes were issued by the British Standards Institution, covering a wide range of materials varying from carbon steels to high-alloy steels. At the request of the British Steel Founders' Association, these have recently been reviewed, with the aim of effecting some closer unification in the general requirements for such materials. The standard now issued contains the results of this review. It consists of two parts, the first dealing with general requirements common to all the types of casting material covered (process of manufacture, testing and inspection, etc.), the second concerned with the individual compositions, properties and treatment of the sixteen types of material in cast form.

Although the whole of the steel-castings specifications have thus been gathered into one schedule, the identity of the respective materials is preserved by reference to the numbers of the B.S. specifications which have previously governed supply of the individual types.

Nickel-containing casting materials are represented by three broad types:—

(1) Austenitic chromium-nickel steel, with or without niobium or titanium.
(2) Austenitic chromium-nickel-molybdenum steels, with or without niobium or titanium.
(3) Heat-resisting high-alloy chromium-nickel steels of six grades, containing varying percentages of chromium and nickel.

Appendices to the specifications contain (A) recommendations on welding procedure and pre- and post-welding treatments, (B) recommended dimensions for standard proportional round test pieces, and (C) notes on points on which agreement is required between manufacturer and purchaser.

Columbium (Niobium), Boron, Calcium and Zirconium in Nickel-containing Materials

R. A. GRANGE *et al.*: 'Boron, Calcium, Columbium and Zirconium in Iron and Steel.'
Published, for The Engineering Foundation, by *John Wiley and Sons, Inc., New York and by Chapman and Hall, Ltd., London*, 1957; 533 pp. Price 112/-.

This volume is the latest of the Alloys of Iron Monographs, a series which has for many years been valued as one of the foremost reference works in metallurgical literature. The individual members of the series are planned to provide concise but comprehensive summaries of available data, as reported in the technical literature of the world, on the effect of selected metals on carbon steel and on simple and complex alloy steels and cast irons. The information is correlated and critically assessed by the specialist authors who prepare the respective volumes, and each monograph is reviewed in manuscript by others qualified to evaluate the subject matter, and finally by the Iron Alloys Committee, members of which are representative of the fields covered. The final volumes thus carry guarantee of unusually wide coverage and authority.

The individual elements dealt with in this volume are, in greater or lesser measure, all associated with many types of material, and the summary of information provided by the new monograph is likely to prove valuable to a wide range of metallurgists and engineers. All the four metals are used, in varying ways, in various types of nickel-containing steels and alloys, e.g., boron to 'reinforce' the hardenability of low-alloy steels; calcium as a cleansing agent in alloy steels and in cast iron; niobium as stabilizer in austenitic steels, and as an integral constituent of high-temperature alloys; zirconium for improvement in properties of alloy steels.

As in all the Alloys of Iron monographs, the chronological *bibliographies* which link with the text are a particularly valuable feature.

Cast Precipitation-Hardening Stainless Steel (L. 17)

D. C. EKEY and E. V. BLACK: '17-4 P.H. Castings: Strong and Corrosion-Resistant.'
Materials in Design Engineering (formerly *Materials and Methods*), 1957, vol. 46, July, pp. 105-7.

The steel described, L. 17, is the cast version of the precipitation-hardening stainless wrought steel designated 17-4 P.H. The Lebanon Steel Company, by whom the steel is made, give the following as a typical composition: carbon 0·07 max., silicon 1·00 max., manganese 1·00 max., chromium 15·25–17·25, nickel 3·00–5·00, copper 2·30–3·00, sulphur 0·04 max., phosphorus 0·04 max., per cent.

A two-stage heat-treatment is needed to develop optimum properties in the steel. Solution treatment in the range 1900°–2100°F. (1035°–1150°C.), for a period depending on the section-thickness of the casting, is followed by precipitation-hardening heating for one hour at 875°F. (465°C.) and air cooling. The mechanical properties can be varied by modification of the thermal treatment used, e.g., by hardening at 1050°F. (565°C.): typical values obtainable by the two treatments are given in this note. Retention of a large proportion of the mechanical strength at elevated temperatures renders the steel suitable for use in some jet-engine components; properties reported as typical are tabulated on p. 208.

It is stated that laboratory and field tests indicate the corrosion-resistance of the L.17 steel as being superior to that of 12 per cent. chromium steel and approaching that of the 18-8 chromium-nickel type. It is particularly resistant to corrosion and pitting in salt water, and is recommended for use in mildly corrosive conditions in applications for which high strength combined with anti-galling properties is required. The condition of the metal is an important factor in relation to corrosion-resistance; the best behaviour is obtained in steel solution-treated, and then aged at 875°F. (465°C.). Precipitation-hardening

Properties of Cast Precipitation-Hardening Steel L.17

(see abstract on pp. 207-8)

	700°F. (370°C.)		800°F. (425°C.)	
	p.s.i.	t.s.i.	p.s.i.	t.s.i.
Tensile Strength	158,000	70·5	157,500	70·3
Yield Strength (0·2 per cent. offset) ..	138,000	61·6	137,500	61·4
Stress-Rupture				
100-hour	134,000	59·8	130,000	58·0
1,000-hour	130,000	58·0	89,000	39·75
Creep Strength				
0·1 per cent. in 1,000 hours	120,000	53·6	50,000	22·3
0·01 per cent. in 1,000 hours ..	80,000	35·7	—	—

at a higher temperature, e.g., 1025°F. (550°C.), severely impairs resistance to corrosion under the standard boiling 65 per cent. nitric-acid test.

Casting of this type of steel presents some difficulties, but correct design permits regular production of castings free from surface cracking. The steel can be welded by all the methods normally used for austenitic stainless steels, and it is not subject to intergranular attack as a result of the welding operation. The composition of the filler metal used should be similar to that of the parent steel.

This note contains statistically derived charts showing frequency distribution of properties in relation to conditions of precipitation-hardening.

Stress-Corrosion in Austenitic Steels in Hot Water and Steam

W. L. WILLIAMS: 'Chloride and Caustic Stress-Corrosion of Austenitic Stainless Steel in Hot Water and Steam.'

Corrosion, 1957, vol. 13, Aug., pp. 539t–45t.

This further paper on stress-corrosion cracking forms an interesting complement to the report by EDELEANU see (*Jnl. Iron and Steel Inst.*, 1957, vol. 186, pp. 406–22; *Nickel Bulletin*, 1957, vol. 30, No. 10, p. 189).

The report is introduced by a short note on the significance of the subject in relation to marine engineering, as well as to industrial operations. The experiments recorded in the paper were carried out under the aegis of the U.S. Navy.

After a condensed review of outstanding literature dealing with the phenomenon, and with theories which have been advanced to explain it, the author gives consideration to the inter-related casual factors which are of major importance: composition of the steel; its condition, as affected by rolling practice, heat-treatment, microstructure and surface finish; the magnitude of the applied stress and of the residual internal stress; temperature, and time.

In summary of results obtained to date, attention is directed to the conclusions reached by HOAR and HINES that 'it is unlikely that practical problems of stress-corrosion cracking of 18–8 type chromium-nickel steels can be solved by attention to alloy composition, by heat, mechanical or surface treatments, or by minimizing applied stress' (*Jnl. Iron and Steel Inst.*, 1956, vol. 182, p. 124). It is noted, also, that tests made in steam and in hot water, reported by WILLIAMS and ECKEL (*Jnl. Amer. Soc. Naval Engineers*, 1956, vol. 68, p. 93) justify the same conclusion. Experience in several countries shows, however, that there are relatively few failures from stress-corrosion cracking in service, and it was therefore the aim of this investigation, as of that recently reported by EDELEANU, to define the environmental conditions which determine whether or not such failure will be likely to occur.

The steel used in the experimental work reported was niobium-stabilized '18–8', in the mill-annealed, as-rolled condition: stress applied was beyond the yield-strength value (in order to accelerate failure); temperature of environment was 500°F. (260°C.), and duration of test was a maximum of about 120 days or until failure, whichever occurred first. Most of the tests were conducted in electrically heated, stainless-steel autoclaves, which were partly filled with water, so that the specimens could be exposed either immersed or in vapour. The specimen used is illustrated in the paper.

Tests were made in high-purity water* and steam from it, and in chloride-bearing water and steam. Behaviour of the steel in the high-purity media indicated that in such conditions austenitic stainless steel which would be likely to be used for fabrication of steam and hot-water systems is unlikely to fail by stress corrosion. Experience in service confirms these findings. In the presence of chlorides, however, stress-corrosion can occur readily in steel immersed or splashed by water or steam containing even a few p.p.m. of such contaminants. Alkaline-phosphate treatment of boiler water has been shown to inhibit stress-corrosion cracking in a contaminated liquid-phase environment, but it is not effective in the steam phase when the specimens are splashed with the treated water. The inhibiting action of such treatment in the liquid phase was demonstrated in these tests on hundreds of specimens exposed in

* High-purity water is defined as water having a total-solids content of less than 1 p.p.m. and a resistivity of at least 500,000 ohm-cm.

various waters containing chloride up to several thousand p.p.m., but it was necessary to take account of some service failures which, in auxiliary boilers of non-magnetic mine sweepers, appeared to contradict this protective effect. Investigation of the operating conditions, combined with simulated-service tests (tilt test) demonstrated the importance of conditions favouring the wetting and steaming from metal surfaces and the concentration of chlorides on them, as being conducive to stress-corrosion cracking, and indicated that the alkaline-phosphate treatment would not inhibit failure in steam-phase conditions in which there was also intermittent wetting of the steel. It was further shown that stress-corrosion from chlorides is dependent on oxygen content, and that prevention of damage may be obtained by limiting either the chloride- or the oxygen-level.

In studying stress-corrosion in caustic solutions, varying amounts of sodium hydroxide were added to water of various compositions; susceptibility to stress-corrosion cracking, under both immersion and steam conditions, was investigated. High concentrations of caustic (of the order of 100,000 p.p.m.) were required to cause stress-corrosion cracking, i.e., a level similar to that required to produce caustic embrittlement of low-alloy ferritic steels. An appreciable degree of superheat is necessary to obtain the 5–10 per cent. caustic concentration which appears to be necessary to cause damage of the stainless steel, and control can be effected by maintenance of a suitable phosphate-caustic ratio.

Resistance of Stainless Steel to Nitric-Acid/Sodium-Dichromate and Nitric-Hydrofluoric Acid Solutions

W. L. WALKER: 'The Corrosion of Type 304L Stainless Steel by Solutions of Nitric-Acid/Sodium-Dichromate and Nitric-Hydrofluoric Acids.'
U.S. Atomic Energy Commission, General Electric Co. Report HW-46369, Oct. 1956; 5 pp.

The report describes short-time (24-hour) tests carried out on very-low-carbon 18–8 chromium-nickel steel, to provide qualitative data on corrosion damage which would be incurred in the use of two solutions employed as repetitive flushing or decontaminating mixtures:—

(*a*) 20 wt. per cent. nitric acid-20 wt. per cent. sodium dichromate,

(*b*) 20 wt. per cent. nitric acid-3 per cent. hydrofluoric acid.

Specimens of the steel were sensitized for one hour at 1250°F. (675°C.), water-quenched, and passivated in 20 wt. per cent. nitric acid, and were then immersed in the test solutions for ½, 1, 2, 4, 8 and 24 hours, at temperatures of 25°, 50° and 75°C., and at the atmospheric boiling points of the respective solutions.

The results show that both mixtures are extremely corrosive: at boiling point the nitric-dichromate solution caused attack at rates as high as 0·2 in. per month, and in the nitric-hydrofluoric solution corrosion was up to 1·0 in. per month. In the former case corrosion appeared to be temperature-dependent: at 25°C. the rate decreased with time, at 50°C. and 75°C. it remained constant, and at the boiling point it increased with time. (Attention is drawn to the fact that solutions of nitric acid containing as little as 2 wt. per cent. of sodium dichromate or any other hexavalent chromium salt, are practically as corrosive as the 20 per cent. solution used in this investigation. A solution of 20 wt. per cent. nitric acid containing only 1·3 wt. per cent. of sodium dichromate is, however, only half as corrosive as the more concentrated mixtures.)

In the nitric-hydrofluoric acid solution there was a progressive increase in rate of corrosion with rise in temperature. In that medium the rate of corrosion slowed down with time, except in the boiling solution, in which rate of attack reached a maximum at four hours and then decreased.

It is concluded that despite the extreme corrosiveness of both the solutions examined, judicious selection of time and temperature of use can minimize damage to a practical degree, permitting their use as repetitive cleaners.

Cleaning of Stainless-Steel Food-Service Equipment

R. E. PARET: 'Stainless Steel: How to Keep it Sparkling.'
Fast Food, 1957, vol. 56, Apr., pp. 48–9 and 90.

The article, which makes practical recommendations on maintenance cleaning of stainless-steel equipment, is in the form of question and answer. The information given is similar to that published in *Restaurant Equipment Dealer*, Sept 1955; reprinted by the INTERNATIONAL NICKEL COMPANY, INC. (see *Nickel Bulletin*, 1956, vol. 29, No. 3, p. 52).

Stainless-Steel Dairy Equipment

'Stainless Steel in the Dairy Industry.'
Dairy Engineering, 1957, vol. 74, Aug., pp. 233, 235, 236–41; special supplement.

From the standpoint of the equipment manufacturer, milk and other dairy produce have two important features: they are very easily contaminated by certain materials, and are extremely corrosive to others. Thus, to meet the exacting standards of hygiene required, while at the same time giving a reasonably economic life, any equipment coming into contact with dairy produce must not only allow of quick and easy cleaning, but must also be completely non-porous and highly resistant to corrosion. It must also be capable of withstanding the high temperatures involved in sterilization and pasteurization processes, and be non-reactive to cleaning media employed and to the lactic acid present in the milk itself. These requirements are satisfied by chromium-nickel stainless steels, which have proved to be most effective for such equipment.

This supplement is planned to give a concise review of recent information on the use of stainless steel in this industry. It contains a series of short articles giving examples of equipment used in margarine

factories, cheese-making and ice-cream production, and components handling milk at various stages, e.g., pipe fittings, pumps, milker units, and butter churns. The publication also contains brief articles on the production of dairy-plant components by the shell-moulding process and on fabrication techniques and welding.

Stainless-Steel-Lined Tank for Storage of Ammonium Nitrate

'2-Million Gallon Tank Lined with Stainless.'
Nickel Topics, 1957, vol. 10, No. 8, p. 5.

A concrete tank 200-ft. in diameter has recently been lined with stainless steel, to form a storage container for ammonium nitrate. Some 60 tons of 14-gauge steel have been used and the re-lining operation involved more than 18,000 ft. of welded seams.

Nickel-Aluminium-Bronze Marine Propellers

See abstract on p. 200.

Cracking of Austenitic-Steel Weld Deposits

W. R. SMITH, L. C. LEMON and J. J. SAKO: 'Crack Sensitivity of Type 308L and 347 Metal-Arc Weld Deposits.'
U.S. Atomic Energy Commission, General Electric Co. Report HW 42075, Mar., 1956; 5 pp.

Previous reports have indicated that the crack sensitivity of austenitic weld metals is greatly influenced by the chemical composition of the electrodes and of the basis metal. The experiments reported here were carried out to evaluate these variables, by comparison of the crack sensitivities of weldments produced by representative specimens of two types of electrode, Type 308L (composition varying as follows: carbon 0·024–0·057, chromium 16·34–20·26, nickel 10–12, per cent.) and Type 347 (chromium 17–19, nickel 9·15–11·04, per cent.). In addition, comparative data were obtained on Types 308L–15 (d.c.) and 308L–16 (a.c.–d.c.) electrodes.

Full details are given of the composition and types of the fourteen electrodes used, and the Arcos Segmented-Groove Notch-Sensitivity Test by which they were evaluated is described and illustrated. The basis metal consisted of an extra-low-carbon straight 18–8 chromium–nickel steel.

It is concluded that, under the conditions described, both Type 308L and Type 347 electrodes produce crack-resistant weld metal if the chromium : nickel ratio is high enough to produce some ferrite.

Welding of Nickel-Chromium-Copper-Molybdenum Steels

H. C. CAMPBELL, T. J. MOORE and S. E. TYSON: 'Corrosion-Resistance of No. 20 and No. 20-Nb Stainless-Steel Welds.'
Welding Jnl., 1957, vol. 36, Aug., pp. 353S–9S.

In 1948 a wrought nickel-chromium-copper-molybdenum steel corresponding to cast Carpenter Stainless 20 was developed, and has already found considerable use in chemical plant, especially in contact with hot sulphuric acid and various organic acids. Many of these uses involve welded construction, and since annealing of fabricated equipment after welding is generally impossible, welding is frequently done with niobium-stabilized electrodes, in order to ensure maximum corrosion-resistance in the as-welded condition. Cracking of welds made with such electrodes has, however, occurred, and crack-sensitivity tests have shown that the presence of niobium is deleterious in this respect. The investigation described in this paper was therefore initiated to examine the relative corrosion-resistance of welds made with unstabilized and niobium-stabilized electrodes, with a view to ascertaining in what conditions the less-crack-sensitive material could safely be used.

The authors describe the main features of the circular-groove specimen used to assess susceptibility to weld cracking, and report at length the results of corrosion tests made on specimens of weld metal deposited from stabilized and unstabilized electrodes. The compositions of the parent plate and of the two types of electrode are shown below.

Table I

Percentage Composition of Weld Metals and Parent Plate

	Undiluted Weld Metals		½-in. Stainless No. 20 Nb Plate
	No. 20	No. 20 Nb	
C	0·04	0·05	0·06
Mn ..	1·45	1·54	0·87
Si	0·17	0·28	0·45
S	0·012	0·014	0·011
P	0·015	0·014	0·019
Cr ..	19·51	19·65	20·73
Ni ..	28·52	28·80	29·77
Mo ..	3·05	2·92	2·47
Nb ..	—	0·81	0·83
Cu ..	3·09	3·12	3·06

The welds were tested in five conditions: (1) as-welded; (2) heated at 1250°F. (675°C.) for 1 hour and air-cooled, the regular sensitizing treatment; (3) heated at 1350°F. (732°C.) for 2 minutes and air-cooled, an alternative sensitizing treatment; (4) heated at 1700°F. (925°C.) for two hours and water-quenched (low-temperature annealing); (5) heated at 1950°F. (1065°C.) for ½ hour and water-quenched (standard annealing treatment).

Specimens in each of these conditions were subjected, in duplicate, to corrosion tests in the following solutions:—

(1) Boiling nitric acid.
Five 48-hour periods in boiling 65 per cent. nitric acid, according to A.S.T.M. Specification A262-55T.

(2) Boiling 10 per cent. sulphuric acid.
Five 48-hour periods.

(3) 10 per cent. nitric-3 per cent. hydrofluoric acids.
Five 2-hour periods at 180°F. (82°C.).

In addition, all-weld-metal specimens, in the as-welded and the standard sensitized conditions, were subjected to the following tests:—

(4) Acidified copper-sulphate test.
Copper-sulphate/sulphuric-acid boiling solution for one period of 72 hours, according to A.S.T.M. Specification A393-55T.

(5) Transverse specimens, in all the conditions of heat-treatment, were subjected to Test 4.

As an additional 'diagnostic' measure, bend tests were made on specimens which had been exposed in the nitric, sulphuric and nitric-hydrofluoric-acid solutions, as well as on those subjected to the standard acidified copper-sulphate test which normally embodies the post-corrosion bend test. The value of these additional tests is discussed and is illustrated by photographs of specimens in which bending proved to be highly discriminating. These tests were supplemented by photomicrographic examination.

The observations made on the behaviour of the specimens show that the niobium-stabilized weld metal is more resistant than the unstabilized composition to severe intergranular attack, particularly in the as-welded and the sensitized conditions. It is therefore recommended that for applications in which the highest possible corrosion-resistance is of primary importance, the niobium-stabilized electrodes be used. If, however, the vessel can be annealed after welding, the two types of electrode should give welds which are equally satisfactorily resistant to corrosion, and the choice of the more crack-resistant unstabilized type may be justified.

Where conditions of severe restraint present a real danger of cracking, e.g., in the welding of heavy sections, the unstabilized electrodes may be a better choice, in spite of the lower corrosion-resistance of the weld. In such cases, a post-welding heat-treatment would be necessary to prepare the welded joint for service under corrosive conditions.

The results of the investigation indicate that annealing can be carried out by heating the weld at 1700°F. (925°C.) for two hours, followed by water-quenching. If it is not possible to apply the preferred 1950°F. (1065°C.) annealing treatment, heating at the lower temperature may be used instead, but with some sacrifice in corrosion-resistance.

Welding of Monel Protection Tubes for Offshore Installations

See abstract on p. 200.

PATENTS

Extraction of Nickel from Lateritic Ores

Nickel is extracted from finely divided lateritic ore by a two-stage process. In the first stage the ore is reduced by heating at a temperature *not above* 600°C. in an atmosphere containing reducing and oxidizing components in specified ratio, and nickel is subsequently extracted from the reduced mass by treatment with carbon monoxide at atmospheric pressure. In the second stage the residue is subjected to a reducing treatment at a temperature *above* 600°C., in an atmosphere similar to that used in the first stage, and nickel is later extracted viâ the carbonyl, by passing carbon monoxide over the reduced mass, at atmospheric pressure. The two-stage treatment gives substantially increased recovery of metal.

MOND NICKEL CO., LTD.
Brit. Pat. 782,242.

Nickel-containing Catalysts

A combined nickel-oxide/tungsten-oxide catalyst is prepared by mixing an aqueous solution of ammonia meta-tungstate (pH 2-5) with an aqueous solution of a nickel salt (e.g., nickel nitrate). A porous carrier material is then impregnated with this solution, dried and calcined.

GULF RESEARCH AND DEVELOPMENT CO.
(inventors, J. B. McKINLEY and W. A. PARDEE).
Brit. Pat. 781,583. (Similar to *U.S. Pat.* 2,703,789.)

Bright Nickel-Plating Baths

Flavones or iso-flavones are added as brightening agents. A typical bath contains (g./L.): nickel sulphate 50, boric acid 30, sodium sulphate 20, quercetin 1·6. The solution has a pH of 4·2-5·8; plating is carried out at 15°-35° C., 10·5-5 v., 0·5-10 amp./cm².

NÉO CHROME (inventor, H. BENNINGHOFF).
French Pat. 1,136,815.

Smoothing Agents for Nickel-Plating Solutions

A series of four patents covers the use, in nickel sulphate, chloride, sulphamate or fluoborate solutions, of coumarin or coumarin derivatives, together with an organic sulphur compound (preferably bidibenzene sulphonamide).

A. H. Du ROSE and J. D. LITTLE, assignors to HARSHAW CHEMICAL CO.
U.S. Pats. 2,782,152; 153; 154; 155.

Electroless Continuous Plating

A catalytic material, e.g., copper, silver, gold, beryllium, germanium, aluminium, carbon, vanadium, molybdenum, tungsten, chromium, selenium, titanium and uranium, is continuously nickel-plated in a bath containing hypophosphite ions and nickel cations, by adding regularly an alkalizing reagent (preferably hydroxyl anions), nickel cations and hypophosphite anions, to replenish the solution.

GENERAL AMERICAN TRANSPORTATION CORPN.
Brit. Pat. 782,363 (similar to *Belgian Pat.* 532,728; *French Pat.* 1,113,830).

Electroless Building-up of Moulds

Moulds are made to dimensions larger than those required and are subsequently coated with nickel until the desired dimensions are obtained. Deposition of the nickel is by the non-electrolytic method, from a bath containing nickel ions and H_3PO_4.

RÉGIE NATIONALE DES USINES RENAULT.
French Pat. 1,139,530.

Precipitation-Hardening Copper-base Alloys

Copper-base alloys characterized by high resistance to creep and good mechanical properties contain aluminium 5·5–8, cobalt 1–2, nickel and/or manganese, 2–6, per cent., copper balance. Silicon up to 0·5 per cent. may also be present. The alloys are precipitation-hardenable: details of solution treatment and precipitation-hardening procedure are given. Such alloys are suitable for use as second-stage gas-turbine heat-interchanger tubes or for gas-turbine compressor blades.

N. C. ASHTON, LTD. (inventor, J. P. DENNISON).
Brit. Pat. 780,004.

Nickel in Tool Alloys

'Chatter' in cutting tools is prevented, and other improvements are obtained, by making at least the shank, and possibly the tool also, from a sintered alloy of tungsten base containing nickel and copper. A typical composition is cited as tungsten 90, nickel 6, copper 4, per cent. Such an alloy is claimed to have a Brinell hardness of 250–285 and a density of 16·96. The tip of the tool is preferably made from a carbide mixture.

MALLORY METALLURGICAL PRODUCTS, LTD.
Brit. Pat. 783,039.

Nickel-Iron Alloy Strip of High Magnetic Permeability

In many of the applications for which high-permeability alloys are used in the telecommunications and radio industries (e.g., for the cores of transformers operating at very high frequencies) the material must be in the form of very thin strip. Alloys commonly used (which are made by conventional melting and casting processes) suffer a sharp fall in initial permeability when reduced to very thin strip. According to the present patent, the alloys are made by sintering a powder mixture of the composition given below, and in strip rolled from such material initial permeability remains substantially constant down to thicknesses of 0·001 in., and does not fall severely when the thickness is as small as 0·0002 in. This improvement is directly traceable to freedom from impurities such as silicon and magnesium, and particularly to the absence of surface layers of small grain-size containing inclusions produced by the oxidation of impurities which are present in similar alloys produced by conventional methods.

Chemical composition is an essential feature of the invention: the main constituents are nickel 70–82, iron 10–20, molybdenum 0–5, copper 0–15, per cent., with control of impurities within the following maximum limits: carbon 0·01, silicon 0·015, sulphur 0·002, nitrogen 0·005, oxygen 0·005, magnesium 0·005, per cent.

MOND NICKEL CO., LTD. (inventors, C. E. RICHARDS, C. G. SMITH and H. EVANS).
Brit. Pat. 782,688.

Nickel Ferrites for Use in Transducers

Ferrites for use in magnetostrictive transducers contain mixed oxides of nickel, cobalt, chromium and iron. Typical compositions are given and methods of production are described.

PLESSEY CO., LTD. (inventors, J. M. HERBERT and C. O'HARA).
Brit. Pat. 782,762.

Welding of Low-Alloy Steels

Improved high-strength welds, free from susceptibility to cracking, can be produced in low-alloy steels by inert-gas-shielded metal-arc welding, using a welding wire of the following composition: carbon 0·004–0·08, silicon 0·3–0·6, manganese 1·2–1·5, nickel 1·1–1·3, vanadium 0·1–0·2, molybdenum 0·3–0·55, per cent., iron balance.

AIR REDUCTION CO., INC.
Brit. Pat. 780,542.

Nickel-Alloy Resistance Materials

In solid plate or tubular sheathed heating devices the heating element consists of two parts, one having high positive temperature coefficient of resistance (preferably an alloy containing nickel 70, iron 30, or nickel 54·5, cobalt 44·5, iron 1, per cent.), and the other a lower temperature coefficient (e.g., an alloy containing nickel 80, chromium 20, per cent.). Such a design provides for high initial loading, followed by reduction to a steady state. Units of such design can be used in boiling plates, immersion heaters and air heaters.

HOTPOINT ELECTRICAL APPLIANCE CO., LTD.
(inventors, W. J. SIMS and G. P. BYFORD).
Brit. Pat. 782,276.

Protection of Molybdenum from Oxidation

Molybdenum is protected against oxidation at elevated temperature by applying at least one intermediate diffusion-barrier layer of iron, nickel, cobalt or alloys of these metals (e.g., by thermal decomposition of the respective carbonyls), heating in a non-oxidizing atmosphere, and finally diffusing a surface layer of chromium, silicon, aluminium, zirconium or alloys of those metals into the first coating layer.

SINTERCAST CORPN. OF AMERICA
(inventor, C. G. GOETZEL).
Brit. Pat. 782,981.

Bright Heat-Treatment of Nickel-Chromium-Iron Alloys

British Patent 771,351 specifies (1) treatment of brass in a container the inner surface of which consists of material free from any metals which, at the annealing temperature used for the brass, would form oxides giving rise to contamination of the atmosphere in the chamber; (2) maintenance of a flow of reducing gas round the brass while it is being annealed.

A later patent, 781,070, applies the same principle to the treatment of alloys including at least one readily oxidizable metal. The atmosphere consists wholly or partly of hydrogen.

The invention is particularly useful for batch bright annealing and for brazing. The examples given relate to heat-treatment of 18-8 chromium-nickel steel and to a nickel-chromium-base alloy. Brazing with Nicrobraz is also mentioned.

GENERAL ELECTRIC CO., LTD.
(inventors, D. M. DOVEY and K. C. RANDLE).
Brit. Pat. 781,070.

Nickel-Alloy Valve-Seat Inserts

Cast valve inserts having improved 'collapse resistance', combined with resistance to lash loss and to corrosion, erosion and wear, are made from alloys containing carbon 2·25-2·75, nickel 37-43, chromium 18-22, cobalt 10-14, tungsten and/or molybdenum 5-7, per cent., iron balance.

THOMPSON PRODUCTS, INC.
(inventors, H. F. PRASSE and A. A. ARMSTRONG).
Brit. Pat. 779,544.

Powder-Metallurgy Production of Stainless-Steel Compacts

Difficulties inherent in the production of compacts from stainless-steel powders, e.g., of the 18-8 chromium-nickel type, are minimized by increasing the strength and density of the 'green' compacts, i.e., prior to sintering. This improvement is effected by adding, to the stainless-steel powder, finely divided nickel powder, and a lubricant is also usually added. An example refers to the following composition: carbon 0·14-0·19, chromium-nickel steel of the 18-8 type, with 5-30 per cent. of nickel powder, 1 per cent. of paraffin wax, and 0·30-0·7 per cent. of calcium stearate.

BIRMINGHAM SMALL ARMS CO., LTD.
(inventors, P. R. MARSHALL and P. J. RIDOUT).
Brit. Pat. 779,949 (similar to *French Pat.* 1,136,174).

Porous Nickel or Stainless-Steel Materials

Porous sheets are produced from metal powder which has been coated with a thermo-setting resin. The procedure includes compacting and heat-treating to cure, and decomposition of the resin, followed by sintering. The powder is preferably stainless steel, nickel or nickel-iron alloy.

GEORGE COHEN SINTEEL, LTD.
Brit. Pat. 781,432. (See also following patent.)

In a subsequent patent, the process according to 781,432 is modified for the production of shaped articles other than sheet.

GEORGE COHEN SINTEEL, LTD.
Brit. Pat. 781,433.

Weldable Corrosion-Resisting Martensitic Stainless Steel

Stainless steel claimed to have improved resistance to intercrystalline corrosion and to transcrystalline stress-corrosion cracking, combined with general corrosion-resistance superior to that of the hardenable 13 per cent. chromium steels, is of the following composition: carbon 0·03-0·1, chromium 16-18, nickel 3-6, silicon up to 1, manganese up to 1, per cent., niobium $>8\times C$, or titanium $>5\times C$, iron balance. Heat-treatment is also claimed.

The statement that steels within these limits of composition give improved resistance to stress-corrosion cracking is supported by information on their behaviour in chloride-containing solutions and in caustic-contaminated water and steam.

J. I. MORLEY, C. SYKES and R. M. N. GRAY.
Brit. Pat. 782,172.

Grit Blasting and Electropolishing of Stainless Steels

Stainless steels are finished by grit blasting followed by electropolishing. The preferred polishing solution is an aqueous mixture of sulphuric acid and phosphoric acid: a typical composition is given as follows: H_3PO_4 20, H_2SO_4 44, aniline 0-2, per cent., H_2O balance. The solution is operated at 50°-60°C., at a current density of 1·1 amp./sq. in. Treatment is for 1½ minutes.

G. KENT, LTD. (inventor, E. M. WALSH).
Brit. Pat. 776,147.

Complex Nickel-Alloy Welding Rods

Welding rods are made by impregnating a base alloy with a metallic carbide, and sintering. The base alloy preferably contains nickel 60-80, chromium 10-20, boron 2-6, silicon 0·5-0·6, per cent.

R. D. WASSERMANN, assignor to STÉ. DE SOUDURES CASTOLIN S.A.
Swiss Pat. 318,254.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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